TRANSACTIONS.

I. PRESIDENTIAL ADDRESSES.

A THEORY OF THE COSMOS.

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An address delivered at McPherson, December 29, 1899, before the thirty-second annual meeting of the Kansas Academy of Science.

Man's attitude to the external world has ever been that of a great question mark, and at no time in the history of the race has mere assertion carried so little weight as at the present time. Every statement must be backed by some evidence of truth, some argument for its validity. New knowledge is always built on previous knowledge; and both are accepted only in so far as they are confirmatory of each other.

Among the very first questions which come to the inquiring mind are: How came this world into being? Whence the sun, the moon, the stars? What is this material world about us, anyway? What child has not queried about the support of the earth? These questions are not only put to-day, but they claimed the thought of milleniums ago. Never was question put, however, but some answer was evolved by poet or sage. Thus, many of the legends, heathen and Christian, accounting for the phenomenal world are rich in poetic beauty, and they have soothed the questioning mind, if they have not always entirely satisfied it.

It would doubtless be of much interest right here to recall some of the ideas that have prevailed among various peoples as to the origin of the earth and heavens, and the destiny of their inhabitants; but I shall refrain from so doing, and proceed at once to a consideration of a view of the universe warranted, in my opinion, by the revelations of modern science.

Notwithstanding the great diversity everywhere manifest in the universe, there is an essential unity in it all. The very name "universe" implies such unity. Everything is under the reign of law. There is a wonderful harmony in it all.

The cosmos is defined as "the world or universe considered as a system, perfect in order and arrangement; opposed to chaos."

Our purpose now is to investigate this "order," and so far as possible discover the laws manifest in this "arrangement." Some of these laws have been recognized for ages; others are of more recent discovery. Such are Newton's laws, Kepler's laws, Avogadro's law, Dalton's law, Lane's law, etc. It is not meant that these laws govern the movements and states of matter as a civil law governs the citizens of a state, but merely that they are generalized statements of the conduct of matter. Natural science is nothing more than an orderly investigation into this orderly conduct of matter. One investigation leads to others. No sooner is one truth in nature recognized than it suggests others to be discovered and formulated.

The pervading principle of all nature is harmony. Holding to the truth of this statement, I desire in this paper to carry forward certain generally accepted

hypotheses in physics and chemistry to more ultimate conclusions than, so far as I know, have hitherto been attempted; and thereby I hope to suggest a theory of the cosmos.

Of necessity this discussion will be somewhat speculative; for it will have much to do with the ether, a medium in itself a mere speculation of science, as yet undemonstrated to any of our senses. Light reaches us from the far distant stars. We can conceive of no way whereby that light can come save as a vibration of some intervening medium, and science has named this hypothetical medium the "luminiferous ether." We are safe in admitting its existence as demonstrated by the phenomena of light, heat, and electricity, though we cannot weigh it, nor can we see it, feel, taste or smell it.

A complete theory of the cosmos must account for all phenomena observed. We may grant that heat and light are fully accounted for, but there are other outstanding phenomena as yet unexplained. Some of the unanswered questions are: What is electricity? What is gravity? What is life? The work of the scientific investigator is far from complete. The above questions need but to be mentioned to suggest that, glorious as has been the record of past discovery, the future will far outshine it in brilliancy.

Nature's primal law is harmony. There is endless variation, yet harmony in it all. There is no harper on themes like nature. She discovered that she could propagate a polyp by an egg; and she never forgot the process, even in the perpetuation of the highest of animals, and man must come into the world by the egg route. A simple protozoan cell can make its way in the world by appropriating from all that comes to it only that which is for its good, rejecting all else; and what more is the highest mammal than a great organized aggregate of vitalized, protozoan-like cells, each one of which does that very thing—appropriates from its environment the nutriment it needs, while it rejects all else? The laws of planets about the sun are the laws of satellites about the planets; and they are the same laws for the winds and streams and ocean currents about the earth—the laws of gravitation of bodies about their common center. Why may we not expect these laws to hold in the molecular world of physics and in the atomic world of chemistry? A stone is dropped into a quiet pool, and the laws of the circling waves have been formulated as they apply in the mass movements of fluids. These laws have been applied with success to the explanation of sound propagation in air and to the phenomena of light propagation in the ether. Some have ventured to extend the theory to electric propagation; and why not? Why not go a step further, and find a theory for gravity based on the same laws? Heat, light and electricity are regarded by some as correlated forces. Why not class gravity with them? They are all certainly capable of having their energies interchanged. We find the theory of vibrations good for explaining sound, heat, light, and some apply it to electricity. Why not extend it to the realm of gravity and chemism? The all-pervading harmony in nature certainly encourages us so to do.

In its efforts to unravel the mysteries of the material universe the human mind has ever run up against the hitherto unsurmountable barrier of gravitation. A stone thrown into the air falls to earth again—*why?* The wise have ever declared that it does so because the earth attracts it; and most people have been satisfied with the answer as a simple and complete solution of the problem. But that this was no explanation of the phenomenon was recognized as long ago as the time of Sir Isaac Newton. He himself declared, and we must admit the self-evident truth, that one object cannot act upon another at a distance save by some bond of union between the two. Between the falling stone and the earth

exists no elastic cord whereby the latter pulls the former to itself. How, then, is it that the stone falls to the earth? Why does the moon fall toward the earth? Why do the moon and earth together and all the other planets fall toward the sun? Why does the sun, with his retinue of planets and their satellites, move through space toward some other center? In short, we would ask: Why any of this motion of stars and comets, of suns and satellites? To say that they so move under the law of gravity does not tell us *why* they so move. Newton recognized the force of this; but even his great mind could leave us no plausible explanation. But the two centuries since his time have revealed many things unknown to the great master; and, though the explanation of the common experience of falling is apparently as much wanting now as then, yet perhaps we may collect a few hints in the various fields of science, and on them hinge a theory which may be of interest to contemplate, if not productive of better results.

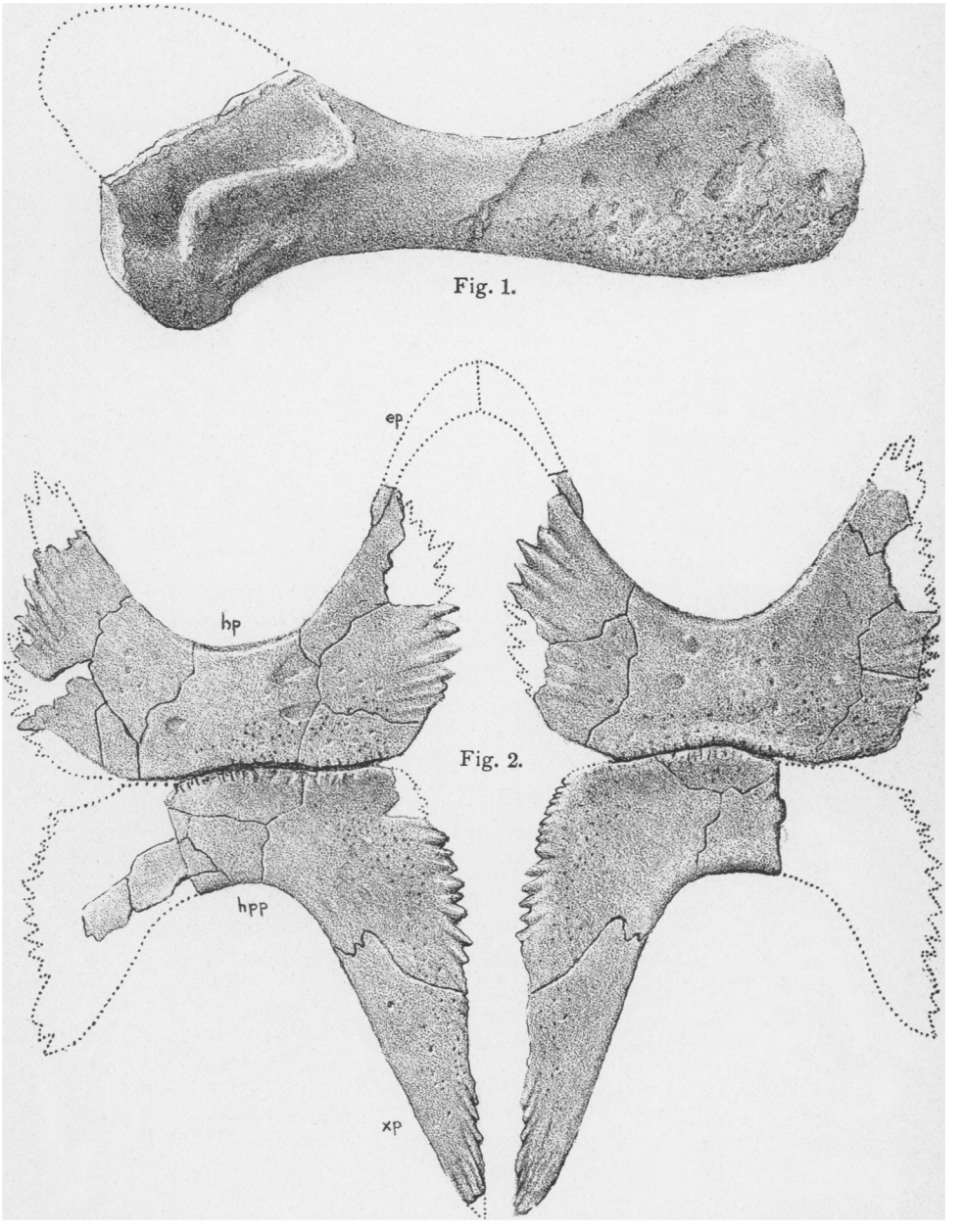
The two great natural sciences are chemistry and physics; for on them hinge all others. The more subtle of the two, chemistry, has for its realm that of the atom; the other, the grosser, physics, deals with the molecule and molecular aggregates, masses. Now, who shall deny that possibly some day we may have a third grand science, more subtle still than either of the others. This third science is as yet unnamed, but its province is broadly hinted at already in the speculations of the other two. Its field shall be the ether; therefore, call it "etherics." True, physics is claiming the ether as a part of its domain in seeking to investigate and explain the phenomena of light and electricity. But is not this clearly a usurpation, inasmuch as light and electricity are admittedly extraneous to the molecule?

And again, chemistry is claiming a part of this field when it attempts to trace the genesis of the elements, as is implied in their grouping into families by the periodic system, as if they had a common progenitor. As yet we can go no farther in our explanations for the formation of the various chemical compounds than to say that they result because of the chemism that exists between the several elements constituting the compound; that is, the affinity that one element has for another. This third science will have for its province the capacity to step back of that affinity and explain *why* it is; why, for instance, oxygen has a stronger affinity for hydrogen than for any other element, and a weaker affinity for fluorin than for any other element; just as also it will tell us *why* a stone tossed in air falls to earth again.

The term "molecule" is a theoretical conception to account for the facts of physics; and it does so very successfully. The atom is a theoretical conception of the chemist, introduced to account for the facts of chemistry. He will tell you that the molecules of a few elements are made up of but a single atom each; while most elemental molecules contain two atoms, and others may contain three, four or six atoms; and a molecule of an organic compound may contain as many as a hundred or more atoms: yet he can never hope to perceive an individual atom by any of his senses, though he may weigh atoms relatively and speak of atomic masses confidently.

Thus we have the molecule for physics, and the atom for chemistry. Our third science, etherics, must also have its unit, and we shall call it the "protatom."

Though our name for this particle smaller than the atom is new, the conception of the existence of such small particles is as old as Prout's theory of the composite nature of atoms, and probably older. More recently, Lockyer's spectroscopic investigations of certain chemical elements point to similar conclusions; and Prof. J. J. Thompson, in a Royal Institute address on the cathode rays, de-



PORTHOCHELYS LATICEPS WILL.

Fig. 1. Ventral view of right Humerus. Three-fourths natural size.
Fig. 2. Plastron. Two-ninths natural size.

livered April 30, 1897, presented mathematical results indicating that the "particles carrying the electric charges" in those rays must be very much smaller than the hydrogen atom.

But before we speak further of the protatom and the role it is to play in our theory of the cosmos, let us examine the prevalent theory of the ether as set forth by modern physicists. By them the ether is defined as a continuous medium pervading all space, intermolecular and interatomic, as well as interstellar; perfectly elastic and exceedingly attenuated; without gravity; imponderable. There are here several qualities assigned to the ether which are contradictory and, for that reason, illogical. How can a substance be elastic and at the same time absolutely continuous? To be elastic it must yield to stress or pressure in the region where the strain is applied, and then, on the removal of the stress, it must return completely to its original position, if perfectly elastic. Now, if a space be already full of the ether as such, how is more of it to be conceived to be crowded into that space? "By making the ether more dense in that particular region," it may be said. But "density" is a relative term, and implies that a greater or less quantity of matter occupies a definite volume. The quality "density" cannot logically be predicated of a substance which is already supposed to *fill* all space. If a measured space is absolutely filled with a substance no more can be introduced, and none can be abstracted without leaving the space incompletely filled. Here, then, we find a plain contradiction of statement, when it is asserted of the ether that it is perfectly elastic and also that it occupies all space.

The ether is also said to be "imponderable." If that be the case, how can it have mass? How can it resist action and thereby produce reaction? That is: how can it propagate energy, or convey energy, or impart energy? That it does all this we know from the phenomena of light, electricity, and radiant heat. In a certain sense a mass may be so positioned that it will "weigh nothing," as would be the case of an object located between the earth and the moon at the place where the "attractive forces" of the planet and satellite exactly neutralize each other; but even in that unique position that object would not be imponderable in the sense in which that term is meant to be applied to the ether. Just as much force would be requisite to impart to a unit mass of that object a velocity of one centimeter in one second out there in space as would be necessary were it at the earth or were it located anywhere else in the universe. Balancing the forces at play on a mass does not render it imponderable. Were the mass imponderable, it could be put in motion at any velocity whatever without the application of force. This is impossible with any mass whatever; therefore the term "imponderable," in its true physical sense, cannot be applied to matter of any kind. Now, we know force is necessary to produce motion in the ether. The carbon filament in an incandescent lamp must be at least red-hot in order to establish those waves in the ether we call light. A dynamo must be run by a steam-engine or by some other power to induce those waves in the ether about conductors, which waves we call electricity, and the energy of which waves brought under control runs our street-cars and turns the night of our cities into day. There is every evidence that a dyne force would be necessary to impart to a gram mass of the ether a velocity of one centimeter in one second, as is the case with all other forms of matter. The ether is therefore ponderable, and a gram mass of it would be such quantity as a force of one dyne could bring to a velocity of one centimeter per second, if applied for that interval.

Let us have a better notion of the ether than this attempt at a conception of an imponderable yet forceful, exceedingly attenuated yet infinitely continuous, perfectly elastic yet incompressible, all-pervading, incomprehensible form of

matter so different from every other form that it is puzzling to know why those who are responsible for such theories of the ether ever thought of it as matter at all.

The ether is undoubtedly a form of matter; and as such it must present all the essential properties of matter: elasticity, impenetrability, inertia, mass, and work must be done to put it in motion. Let us get a conception of the ether which will admit of all these essential properties of matter, and which will eliminate the contradictions of the old theories. Let us think of the ether as made up of protatoms—particles which constitute the atoms of the tangible elements about us everywhere. Let us suppose these protatoms to be separated from each other by distances which are great as compared with their own diameters; and let us conceive of the spaces between these protatoms as absolutely void—nothing there at all. The conception of empty space is not beyond the human mind, as some have contended; for space is only pure extension, which may be occupied by matter or not, according to circumstances.

One more conception is necessary: that of motion. Our protatoms must be in motion. But whence the motion? is asked. As well ask: Whence the matter? Matter and motion of matter are coexistent. These are the two fundamental ideas of the material universe. Upon them is built the cosmos. Is matter eternal? so is the motion of matter. The approach of particle to particle, the recoil, the consequent approach to other particles, and recoil, are as eternal as the matter itself. Whence it is no science can tell, as no science can tell whence the matter with which it deals. Absolute rest, absolute absence of this approach and recession of particles and masses, would be as difficult of explanation did such a condition of affairs exist in nature.

Briefly, the conception of the ether which I desire to suggest is: that it is constituted of minute particles which I call protatoms; these protatoms may be of various sizes, but all are minute as compared with their mean distances apart in the otherwise void space; in this void space they move with a great range of velocities in every direction, and hence they are continually colliding and rebounding, with no diminution, however, of their sum total of energy; for what motion is lost to one protatom, owing to the angle of impact, may be found as imparted to the protatom struck, all being perfectly elastic.

Owing to their varying distances apart and to their variance in size and velocity, a tendency to grouping will arise, if indeed the existence of groups may not be considered as a primal condition. This will be a selective grouping, analogous to that seen in the case of concretions and other grosser aggregates, such as crystals, "pillow witches," hair balls, etc. Groups of like size and weight will show like properties. They will constitute the chemical atoms. This vibration of the ether protatoms will continue to play on the atomic aggregates, not as aggregates, but as they strike and rebound from the individual constituent protatoms of the atoms. Some of the free ether particles may even penetrate to some depth among the protatoms of the atoms before they strike a resisting particle, and thereafter may be a part of the atom, while others at the periphery of the atom will swing out into the free ether, and again become independent protatoms. Thus the atoms are not absolutely constant in their mass, and recent investigations on the atomic weights of some of the elements lend argument to this view. An average mass for the atom would be maintained, the losses under the action of the surrounding ether balancing the gain, as is the case of the formation of pillow witches in a pillow of feathers.*

The atomic aggregates which are comparatively near would shield each other

*See article on "Concretions," Kans. Acad. of Sci. Transactions, vol. XVI, pp. 44-46.

to a greater or less extent from ether impacts on their sides facing each other, and would thereby be *driven* together. Thus would arise the molecules, their sizes also being determined on the same principle as that which determined the sizes of the atoms. Atomic aggregates of like size and vibration associated together would constitute molecules of elements. But when atomic aggregates of unlike size and vibration are brought into proximity they may be driven together in greater numbers, and because of their very difference they may be held together with greater force. Thus very complex molecules may arise, as in organic compounds. Here, then, in the vibration of the protatoms of the ether we find an explanation of chemism.

But we shall find more. The molecules are under the same influence of protatomic vibration, and are driven together by their interior faces being shielded to some degree from impact, thus making a preponderance of impulse on the exterior; and we have aggregates of molecules resulting, ranging in size from those more than microscopically small to those we can handle, and others too large to handle. Thus we find cohesion and adhesion explained. But we have yet more. The masses in turn shield each other from the impacts of ether waves, and the blows are more numerous on their exterior faces than they are on their sides turned toward each other, and in consequence they are driven together, or at least toward each other. Herein we find an explanation of *gravity*. Remember, the impacts are not of protatoms moving immensely long distances; this is no "corpuscular" theory. The motion is a *wave* motion, and the masses are not struck as such; but the individual protatoms at the surface and to some depth have received the impacts, taken up the motion and imparted it to the next series of protatoms toward the interior, then rebound. Thus the whole body is influenced to move by reason of the motion imparted to its constituent protatoms.

Therefore every material body, however small or great, tends to move towards every other body, being *driven* to do so with a tendency directly proportional to their masses, and inversely as the square of their distances apart. To say that they attract each other is meaningless, but to say that they are driven together under the force of *ether vibrations* may be an explanation.

But how is it possible that the external pressures due to ethereal impacts on the two masses are greater than the pressures due to the impacts against the interior faces?

To explain how this may be we will recall a very interesting experiment in the physics of sound, as follows: If two tuning-forks are suspended near to each other and are made to vibrate they will approach each other. Various explanations for this and similar phenomena have been given, the usual one being that they are due to air currents established. The explanation I would offer is: The sound waves of condensed and rarefied air between the two forks meet and neutralize each other to a greater or less extent by crests of condensation meeting troughs of rarefaction, while the pressure of the air on the more remote sides of the forks remains practically the same. Thus the forks are driven together by the excess of pressure from the outer sides.

Now, let us apply this to the ether. According to our theory, the protatoms are in eternal motion, meeting and rebounding continually. For the most part, this motion in the outer ether is chaotic; that is, it lacks rhythm. But even in such a chaotic ether there must exist regions where the protatoms are more numerous and closer together than in other regions. The irregular vibrations striking into such aggregates will be more or less absorbed; that is, the motion will become, to a great extent, a *resultant* motion, belonging to the aggregate as

such, rather than to the protatoms as individuals. Thereafter it will be transmitted and emitted by the aggregate as a regular wave. Of such nature are light waves and all other forms of radiation—they are all induced in the ether by the vibration of aggregates; that is, for the most part, by vibration of atoms and molecules. The motion is no longer one of individual impulse, as it was in the outer chaotic ether, but is now an organized wave. Should there be but one such aggregate, the organized wave would again become broken up by the ultimate preponderance of individual impacts as it moves on into the chaotic ether, and the single aggregate we have been considering would not be shifted in space. But suppose another aggregation of protatoms in the vicinity. This is also receiving chaotic impacts from all sides, and sending out organized waves; but on the face turned toward the neighboring aggregate it is also receiving wave impacts. The waves thus propagated between these neighboring aggregates will necessarily neutralize each other to some extent, as in the case of tuning-forks vibrating in air, and the result is the aggregates are *driven* toward each other. They meet and rebound, or circle about each other, according to their masses, previous motions, and resultant directions taken. They are a "molecule." The same principles hold good for larger aggregates and aggregations of aggregates. *This is gravity.* It is more. It is a persisting principle throughout the cosmos. It is the cause of cohesion, of adhesion, of chemism. Electricity, light, magnetism, are due to more orderly waves. They are the ones we can in a measure handle.

If we can in a measure control these waves between bodies, we can to the extent of that control annul the force of gravity. What more is magnetism than the exercise of such control? A magnet will prevent a bit of iron from falling; that is, the gravity waves between the earth and the bit of iron fall far short of neutralizing each other to the extent that other waves between the magnet and the piece of iron are neutralized; and the latter two are driven together with considerable force.

Again, gravity action is overcome by "static electric charges." What is an "electrified" body? It is one whose atoms and protatoms have been thrown into such a state of vibration that a preponderance of the ether impacts they suffer are harmonized, and the energy of the impacts is given out as that of definite waves in the ether. The waves from a "positively" charged body neutralize those from a "negatively" charged body to an unusually marked degree, and the two are driven together with a very perceptible force. They touch and are "discharged." But what is a "discharge"? It is simply a breaking up of the previously induced condition of regularity of vibration of atoms and protatoms which was called "charging." But how is a body charged? Break a lump of sugar, and the two halves become electrified. The atoms are set into regular vibration by the rupture, just as a tuning-fork is set into vibration by suddenly releasing its prongs from pressure. All frictional charges are due to a sudden separation of particles. But an electric charge may be obtained by induction; so can a tuning-fork be set to vibrating by the sympathetic vibration of another fork of like pitch. Indeed, all forms of electrification, current as well as static, may be said to inhere in vibrations established either by sudden separation of particles, whether by mechanical friction or by chemical action, or the vibrations are established by induction.

Furthermore, we may know now what becomes of energy radiated "into space." Of all the heat and light radiated from the sun, only a very small part falls upon the members of the solar system, and a still smaller portion strikes the members of other systems. The sun is but a point of light as viewed from the other stars.

What of the vast, apparently wasted, energy that must go on, and on, and on, through space? Is it lost? I answer, No. It abides; it remains in the ether; not as light, not as heat radiation, not as electricity, ultimately, but as *gravity*, reduced to the primal condition of energy; chaotic, protatomic vibration of the ether. From this primal condition it may again be reorganized into regular waves of definite length, and therefore of definite name, as light, or heat radiation, or electricity, by traversing atomic and molecular aggregates. Thus do we round out one more cycle in this great universe of cycles.

An astronomical problem of interest is the question of friction in the outer ether. Why are not the planets and comets retarded in their courses by friction with the ether? Even the tails of comets are not slowed up in their passage about the sun. Instead of these bodies being retarded by the ether, our theory discovers in the ether their very propelling medium. It is the ether impacts which are driving the comets toward the sun and the sun toward the comets by the organization of waves between them, as between all other bodies, as we have endeavored to show.

By our theory of the cosmos, electricity and gravity are considered as forms of energy inhering in the ether vibrations. By this view they become correlated with light and radiant heat. Thus we avoid the old, cumbrous and inexplicable conception of electricity, which regards it to be a form of fluid matter, imponderable, incompressible, entangled as it were in the ether. We affirm of such a notion of the "electric matter" what we have asserted of a like conception of the ether: that it is illogical, and, therefore, impossible.

Gravity is usually spoken of loosely as a force, and not as a form of energy. Force is a tendency to produce or alter motion in matter. The force may be exerted and measured without the motion actually resulting, because it may be balanced by an equal counteracting tendency. We have found by our theory that gravity is inherent in the moving protatoms of the ether. It is there by virtue of that motion, and is therefore a form of energy, just as heat is present in a material mass by reason of the vibration of its molecules, and is therefore a form of energy. Motion of matter is essential to all forms of energy. Without motion the idea of energy is inconceivable.

Briefly stated, the conception of the cosmos which I wish to suggest is: The material universe is made up of matter in eternal motion. All is matter and motion of matter. The masses, as we know them about us, large and small, are made up of molecules in motion. These molecules may meet and rebound or swing about each other in their movements, but they are never in permanent contact. So small are they that their existence cannot be detected as individuals by any of our senses, yet their existence is established by the principles of physics. The molecules in turn are conceived to be made up of atoms, to satisfy the demands of chemistry. And now, I hold that the atoms must be subdivided into protatoms, to conform to the demands of etherics; that in the motion of these various aggregates of matter inheres the energy of the universe—as energy of mass motion in the movements of sensible masses; as heat in the motion of molecules; as chemism in the motion of atoms; and as light, radiant heat, electricity, magnetism, gravity, in the motion of the protatoms of the ether; that the ether itself is made up of protatoms, as yet unassembled into atoms, more or less evenly distributed, with absolutely void spaces between them; that across these spaces the protatoms move unhindered until they collide with other moving protatoms, when they rebound with undiminished energy because of their perfect elasticity: that the energy of this ultimate individual protatomic vibration is gravity; that this protatomic vibration becomes transformed in the atomic, molecular, and mass

aggregates into the resultant energy of organized waves; that the waves which are emitted on the sides of bodies facing each other are more or less neutralized, thus allowing of a greater pressure on the outer sides, and thereby causing the bodies to be driven together. Finally, the theory presented discovers a complete cycle in the transformation of energy. Hitherto the energy dissipated into space has found no explanation for its conservation and return. The theory presented herein recovers that energy in gravity, ready to be again transformed in endless recurrent changes.

A BRIEF OUTLINE OF ECOLOGY.

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An address delivered before the Academy, at Topeka, December 29, 1900.

I have been requested by the Academy to present a paper upon the subject of "Ecology." On account of numerous other duties, I have decided to make this subject the title of the address expected of me this year as retiring president.

The word "ecology" is of recent origin. The word seems to have been first used in 1891, by Strasburger, a German botanist. He says, in his discussion of the subject: "Anpassungslehre oder Œcologie, falschlich jetzt als Biologie bezeichnet, da auch doch Biologie uberhaupt die Lehre von den lebenden Wesen ist." In 1893 the Madison congress considered, among other matters, the terminology of plant physiology. It fell to me, as a member of the committee appointed to formulate suggestions, to present our conclusions upon the subject of ecology. It was recommended that the term "ecology" be used for that part of plant physiology which deals with the adaptive processes of plants, and that it be spelled with an "e" instead of "œ." This recommendation was adopted, and the word has since come into general use. Although the word is of recent origin, the subject itself has received attention for a much longer period. In Germany, it has been known under the name of "biologie," and, for want of a better term, the corresponding English word "biology" has been used in this country. But biology, properly, refers to the science of life, and includes the two branches, zoölogy and botany. Hence this second use of the word produces confusion.

It is difficult to accurately define ecology, as it cannot be easily limited; but, as generally accepted, it includes all that part of physiology in general which deals with the effect of environment upon the plant. Physiology, proper, deals with the action of physical and chemical forces within the plant. A study of the chemical changes connected with nutrition, or the physical forces involved in water absorption, is in the domain of physiology. A study of the methods by which a plant adapts itself to changes in the amount of water or light, or the different soil conditions, is in the domain of ecology. It will be seen that ecology deals with organs and physiology with the cell. But in one-celled organisms or even in little differentiated multicellular organisms this difference becomes reduced to zero. While it is convenient to segregate certain vital phenomena under a separate name, it must not be understood that these phenomena are not brought about by the same forces that are considered in physiology. But physiology deals with its phenomena as identical with phenomena in the physical world, and is constantly trying to reduce these phenomena to their lowest terms; as it were, to coordinate them with similar phenomena observed in the laboratory. To the physiologist the cell forming the root hair is an example of osmosis, and its action can be successfully reproduced in the laboratory. The living protoplasmic membrane is the osmotic membrane; the soil water, a weak solution of